Claims

What is claimed is:

1. A tool for determining subsurface properties, comprising:
   an elongated body having a longitudinal axis and adapted for disposal within a subsurface borehole;
   a transmitter disposed on the body and adapted to transmit electromagnetic energy; and
   a receiver disposed on the body at a distance less than six inches (15 cm) from the transmitter and adapted to receive electromagnetic energy;
   wherein the transmitter or receiver comprises at least one antenna with its axis tilted with respect to the longitudinal body axis.

2. The tool of claim 1, wherein the transmitter and receiver are disposed in a cavity within the elongated body.

3. The tool of claim 2, wherein the transmitter and receiver are disposed in an insulating material within the cavity.

4. The tool of claim 1, wherein the transmitter is adapted to operate at a frequency between 1 MHz and 500 MHz.

5. The tool of claim 1, wherein the distance between the transmitter and receiver is less than two inches (5 cm).

6. The tool of claim 1, wherein the transmitter comprises two antennas with their axes substantially orthogonal to one another.

7. The tool of claim 1, wherein the receiver comprises two antennas with their axes substantially orthogonal to one another.

8. The tool of claim 1, wherein the transmitter comprises an antenna with its axis substantially aligned with the longitudinal axis of the elongated body.

9. The tool of claim 1, wherein the receiver comprises an antenna with its axis substantially aligned with the longitudinal axis of the elongated body.

10. The tool of claim 1, wherein the receiver and transmitter each comprise an antenna with its axis substantially aligned with the longitudinal axis of the elongated body.

11. The tool of claim 1, wherein the transmitter comprises an antenna with its axis substantially perpendicular to the longitudinal axis of the elongated body.

12. The tool of claim 1, wherein the receiver comprises an antenna with its axis substantially perpendicular to the longitudinal axis of the elongated body.

13. The tool of claim 1, wherein the transmitter and receiver each comprise an antenna with its axis substantially perpendicular to the longitudinal axis of the elongated body.

14. The tool of claim 13, the receiver and transmitter each further comprising an antenna with its axis substantially aligned with the longitudinal axis of the elongated body.

15. The tool of claim 1, wherein the elongated body comprises an extendable section on which the cavity including the transmitter and receiver are disposed.

16. The tool of claim 1, wherein the elongated body comprises a protruding section on which the cavity including the transmitter and receiver are disposed.

17. The tool of claim 1, wherein the elongated body is adapted for subsurface disposal during drilling of the borehole.

18. The tool of claim 1, wherein the receiver or transmitter comprises a tri-axial antenna system adapted to transmit or receive electromagnetic energy.

19. A method for determining subsurface properties using a tool adapted for disposal within a borehole traversing an earth formation, the tool having an elongated body with a longitudinal axis and including a transmitter and a receiver disposed thereon, the receiver located at a distance less than six inches (15 cm) from the transmitter, the transmitter or receiver comprising at least one antenna with its axis tilted with respect to the tool axis, comprising:

a) disposing the tool within the borehole;

b) energizing the transmitter to emit electromagnetic energy;

c) acquiring a subsurface electromagnetic measurement using the receiver; and

d) determining a subsurface property using the electromagnetic measurement.

20. The method of claim 19, wherein step (a) includes extending a section of the tool, on which the transmitter and receiver are disposed, toward a wall of the borehole.

21. The method of claim 19, wherein the distance between the transmitter and receiver is less than two inches (5 cm).

22. The method of claim 19, wherein step (a) includes rotating the tool within the borehole.

23. The method of claim 19, wherein the tool is disposed within the borehole during drilling of the borehole.

24. The method of claim 19, wherein the transmitter comprises two antennas with their axes substantially orthogonal to one another.

25. The method of claim 24, wherein the receiver comprises two antennas with their axes substantially orthogonal to one another.

26. The method of claim 25, further comprising determining electromagnetic couplings between an x-axis receiver antenna and a z-axis transmitter antenna.

27. The method of claim 25, further comprising determining electromagnetic couplings between a z-axis receiver antenna and an x-axis transmitter antenna.

28. The method of claim 25, further comprising determining electromagnetic couplings between an x-axis receiver antenna and an x-axis transmitter antenna.

29. The method of claim 25, further comprising determining electromagnetic couplings between a z-axis receiver antenna and a z-axis transmitter antenna.

30. The method of claim 19, further comprising determining electromagnetic couplings between the transmitter and receiver to determine one of a subsurface layer boundary, a distance to the borehole wall, or a dip angle of a dipping plane within the subsurface formation.

31. The method of claim 30, further comprising using the sum or difference of the couplings to determine one of a subsurface layer boundary, a distance to the borehole wall, or a dip angle of a dipping plane within the subsurface formation.

32. The method of claim 19, wherein the subsurface electromagnetic measurement consists of an electromagnetic induction or propagation response of the formation.

33. The method of claim 19, further comprising determining electromagnetic couplings between the transmitter and receiver according to:

$$V_{zx} - V_{xz}$$

where

V_{zx} is the voltage measured on an x-axis receiver antenna associated with activation of a z-axis transmitter antenna, and

V_{xz} is the voltage measured on a z-axis receiver antenna associated with activation of an x-axis transmitter antenna.

34. The method of claim 19, further comprising determining electromagnetic couplings between the transmitter and receiver according to:

$$V_{zx} + V_{xz}$$

where

V_{zx} is the voltage measured on an x-axis receiver antenna associated with activation of a z-axis transmitter antenna, and

V_{xz} is the voltage measured on a z-axis receiver antenna associated with activation of an x-axis transmitter antenna.

35. The method of claim 19, further comprising determining the electromagnetic coupling between a z-axis transmitter antenna and a z-axis receiver antenna.

36. The method of claim 19, further comprising determining the electromagnetic coupling between an x-axis transmitter antenna and an x-axis receiver antenna.

37. The method of claim 19, wherein the receiver or transmitter comprises a tri-axial antenna system adapted to transmit or receive electromagnetic energy.